Advanced engine control methodologies for the series-hybrid vehicle

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Paul Stewart
Professor of Control Engineering
Founding Head - Engineering

UNIVERSITY OF LINCOLN

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PRESENTATION CONTENTS

- EV Architectures
- Series-Hybrid Control Issues

- X-by-wire – Electronic Throttle Control

- Engine and DC Link set point control issues
- PID and Fuzzy Logic control

- Engine time delay control issues
- Predictive engine control

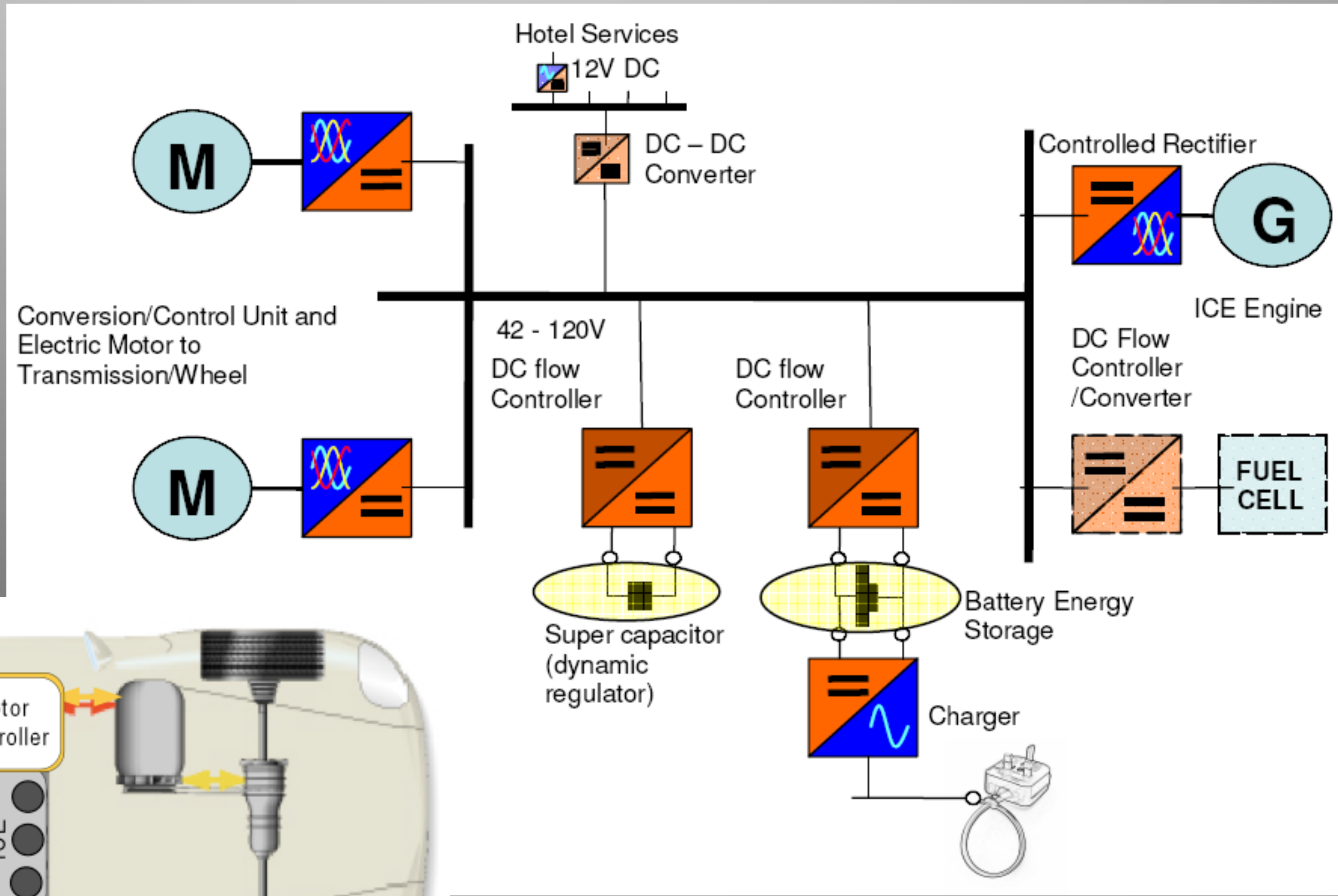
- Controller design by Genetic Programming

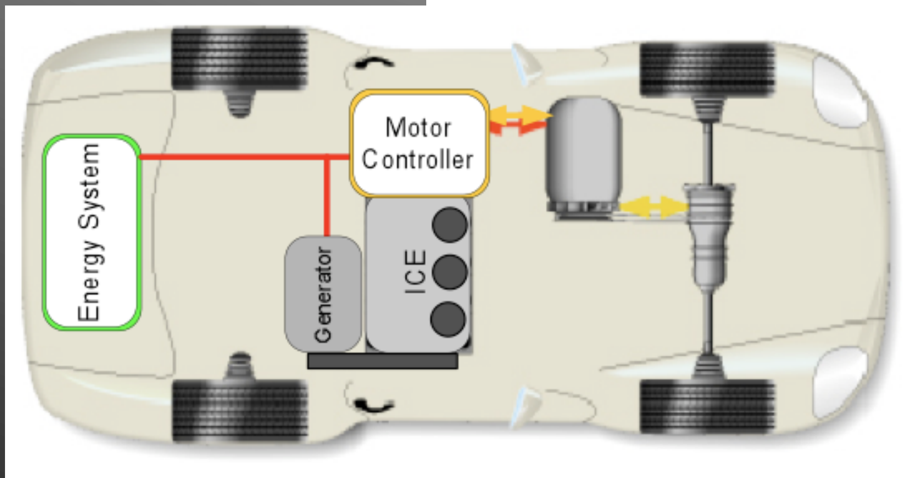
- Engine in the loop design methods

- A-archetype city electric vehicle
- B/C-archetype mild hybrid
- C/D-archetype series hybrid
- C/D-archetype mechanical hybrid
- Medium commercial vehicle hydraulic hybrid

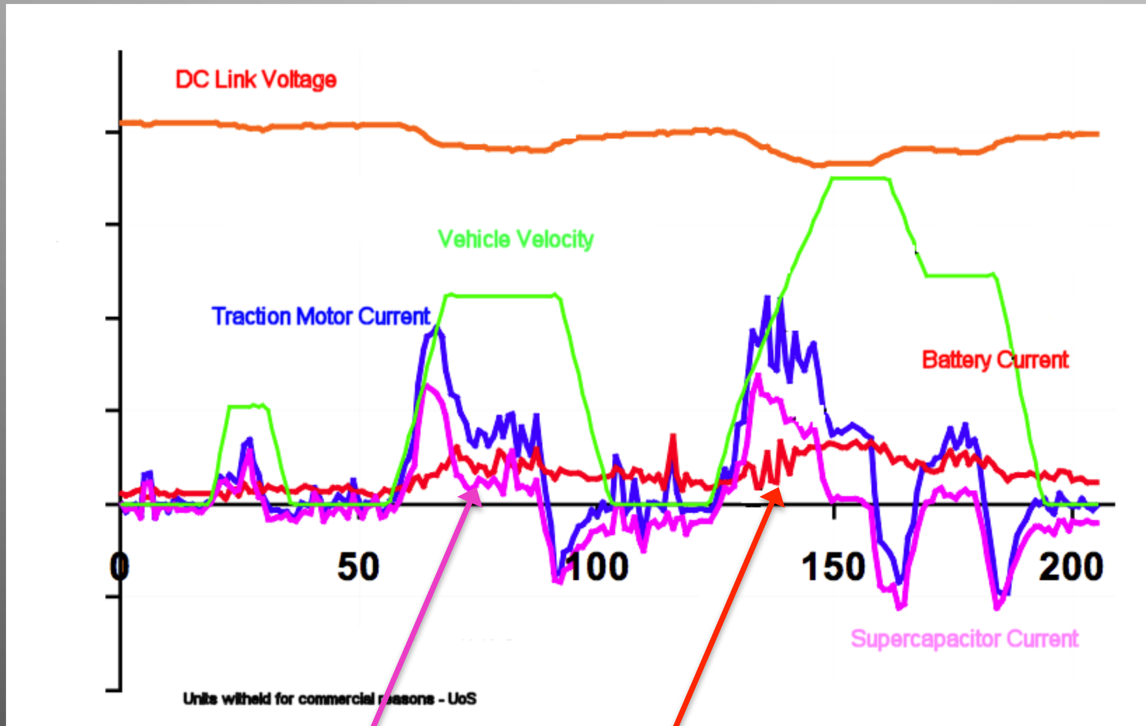
	A: Electric Vehicle	B/C: Mild hybrid	C/D: Series hybrid	C/D: Mechanical hybrid	Commercial : Hydraulic hybrid
LI-ION					
Other battery					
Supercapacitor					
Hydrogen (compressed)					
Hydrogen (other)					
Flywheel					
Hydraulic					
Compressed air					

Defining archetypes of EV / HEV/Hybrid





Candidate typical architectures

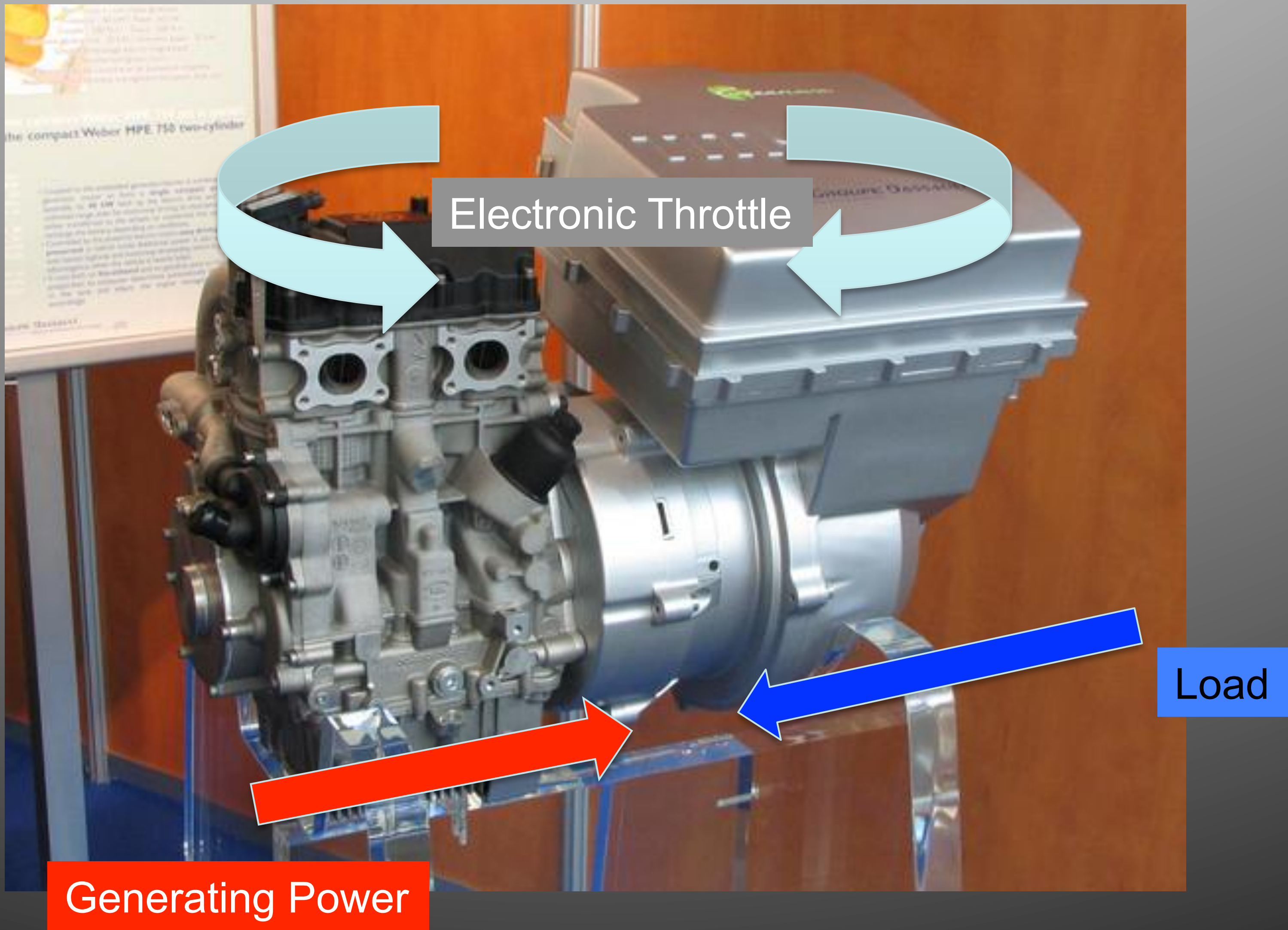


In an HEV, the engine sees the equivalent of supercapacitor current and battery current as a reaction torque on the attached generator driving the traction motor load.

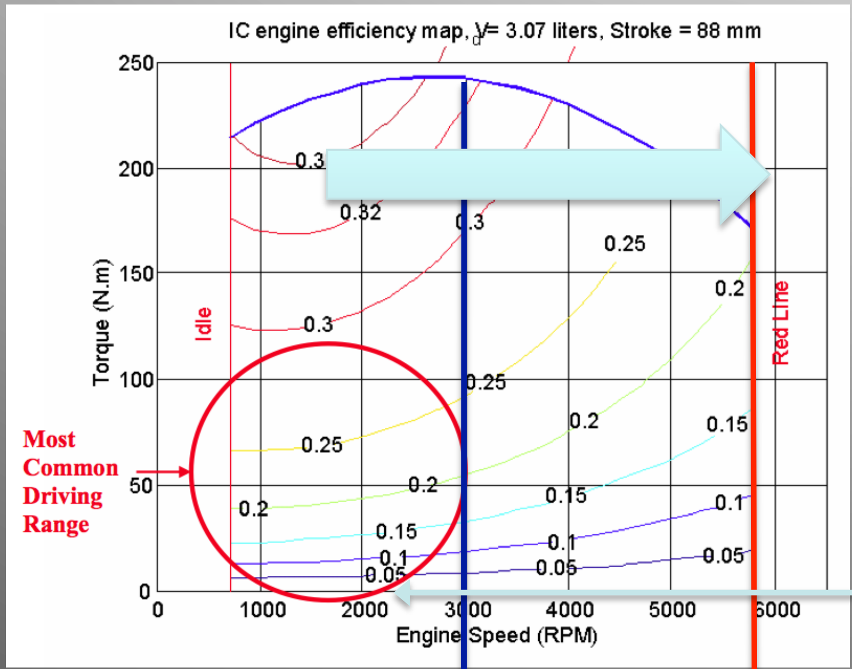
- Supercapacitors supply transient energy for acceleration
- Transient current 'tracks' traction motor loads
- Even with transient energy store, DC link voltage is not stiff

- DC link capacitors sized for 'stiff' link voltage
- Stable link voltage desirable for weight and control considerations

EV experimental waveforms

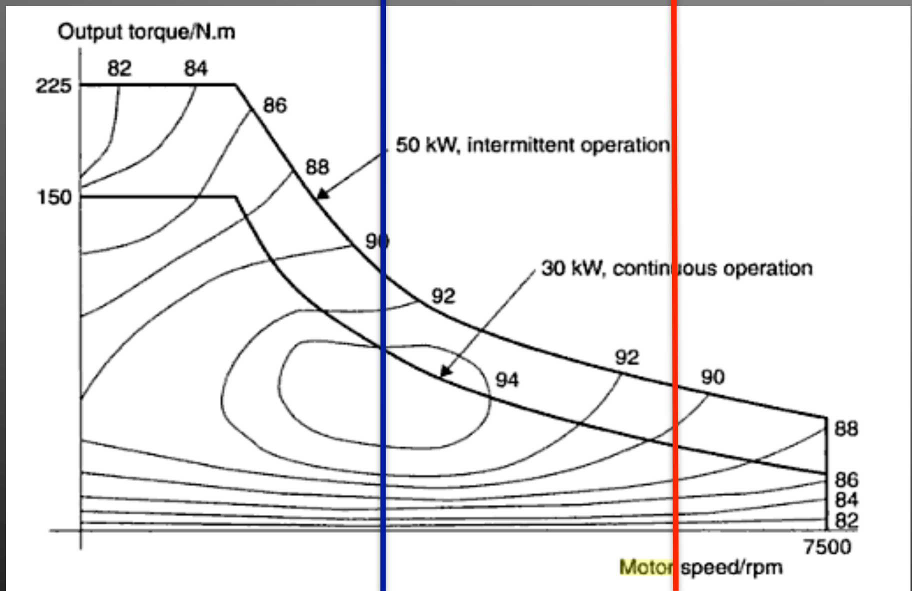


Range extender control principle



Optimised engine design for range extender would bring the map this way

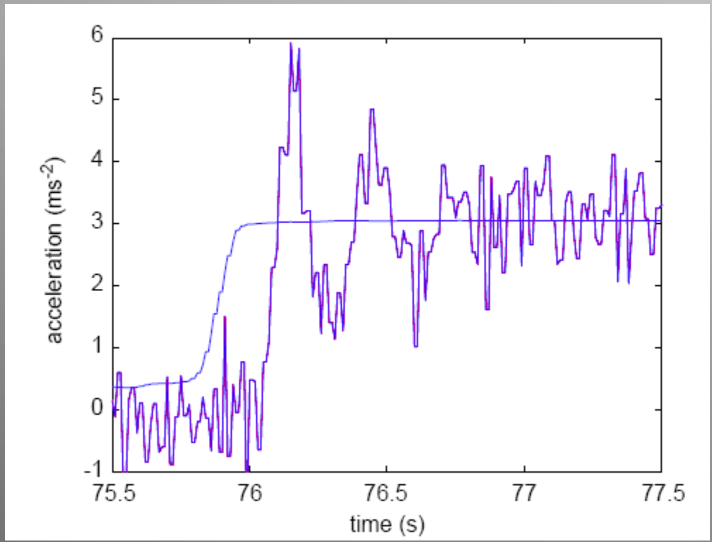
Typical range for IC standard drivetrains



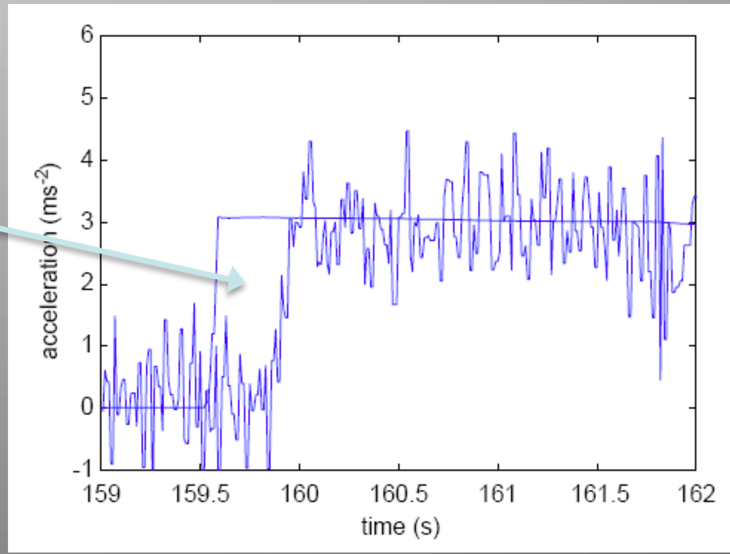
Load optimised generator
Approx. 94% efficient up to 30kW electrical load line

HEV load line

Control Engineering Practice 13 (2005) 257-264



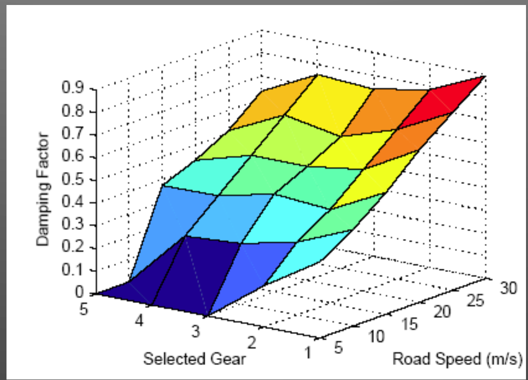
System lag



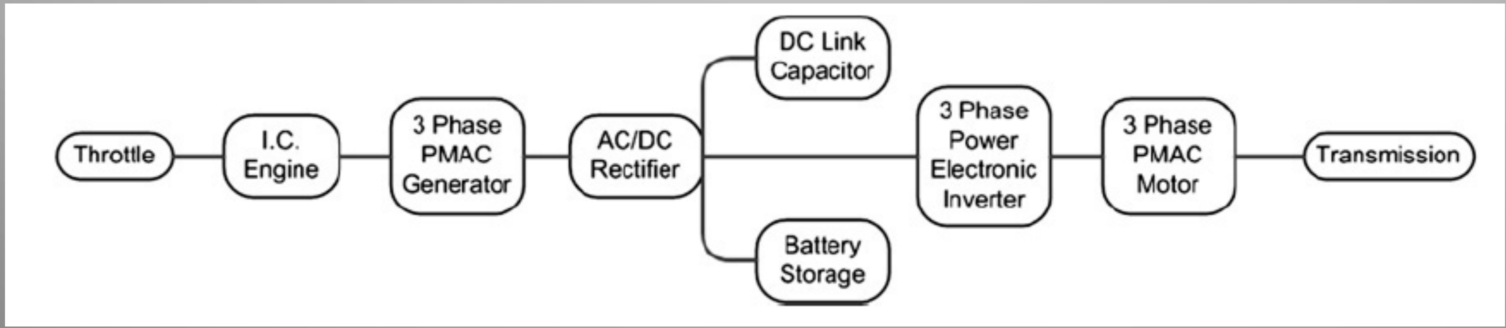
Drivetrain ‘shuffle’ control by electronic throttle

Feedback controller derived from damping factor map

Controller gains optimised by Multiobjective Genetic Algorithm



Drivetrain control by electronic throttle

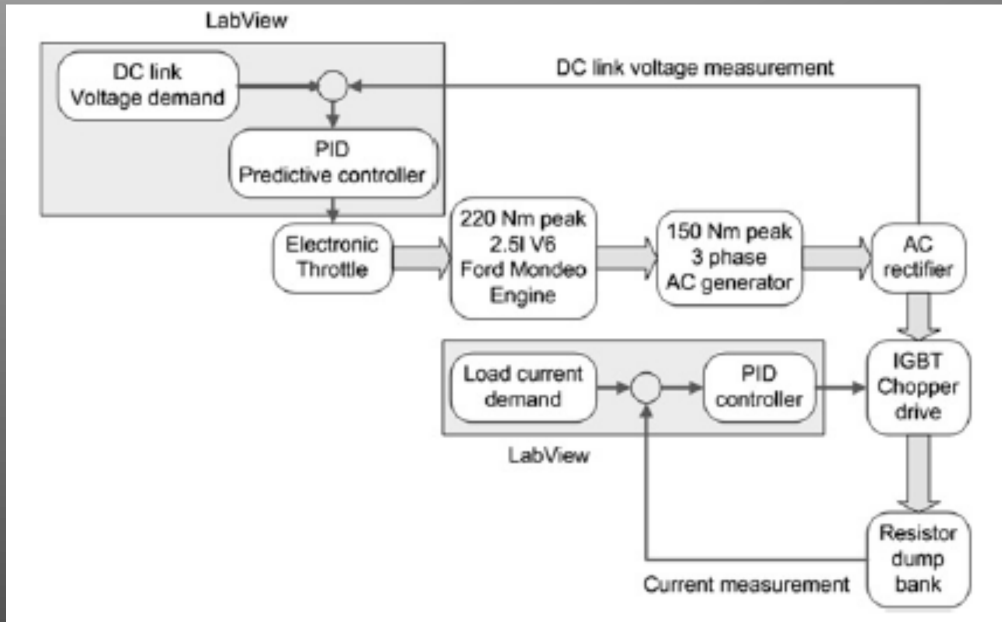


HEV driveline emulated in lab by engine – generator – controllable load

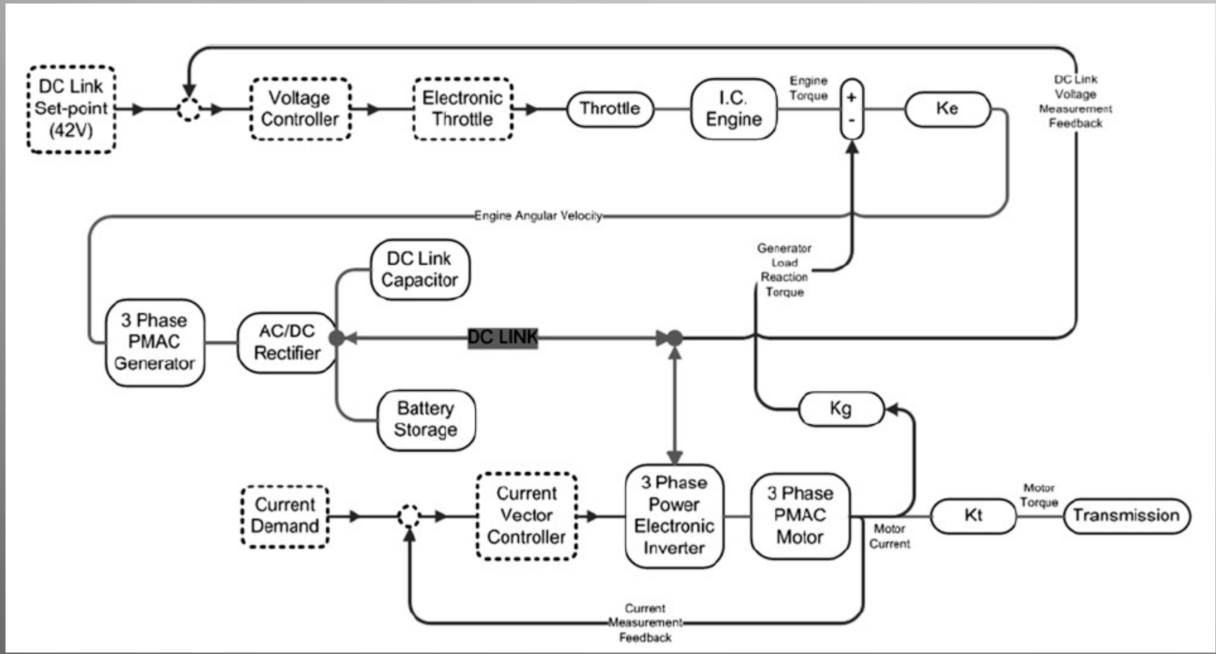
Allows examination of standard closed loop control methodologies – PID etc.

Closed loop control of DC Link voltage

Rectification by bi-directional 3-phase inverter

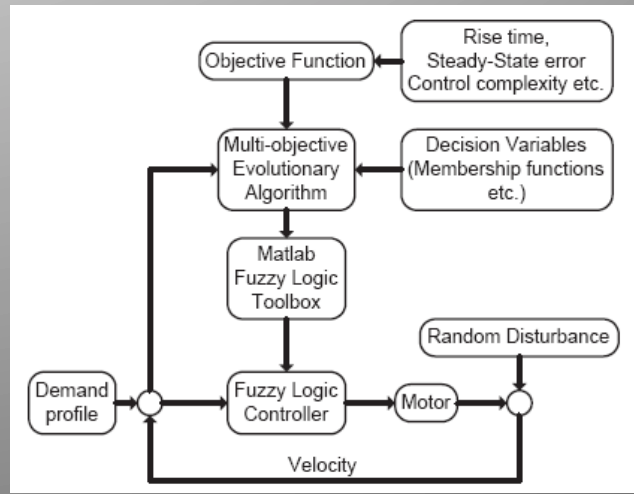


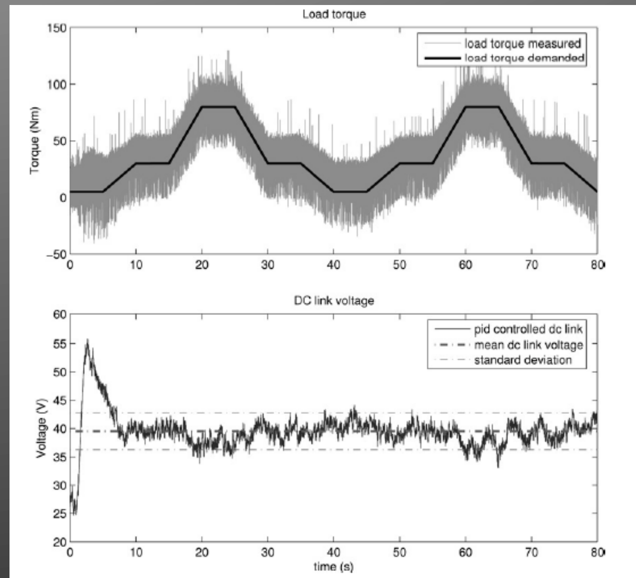
Experimental drivetrain



System model

Fuzzy logic + PID control design





PID and Fuzzy logic controllers designed around system model
Controller parameters tuned by Genetic algorithm
Experimental work reveals effect of system time delay

DC link voltage read via DC-DC converter on ‘virtual’ 42V bus

PID and Fuzzy logic engine control

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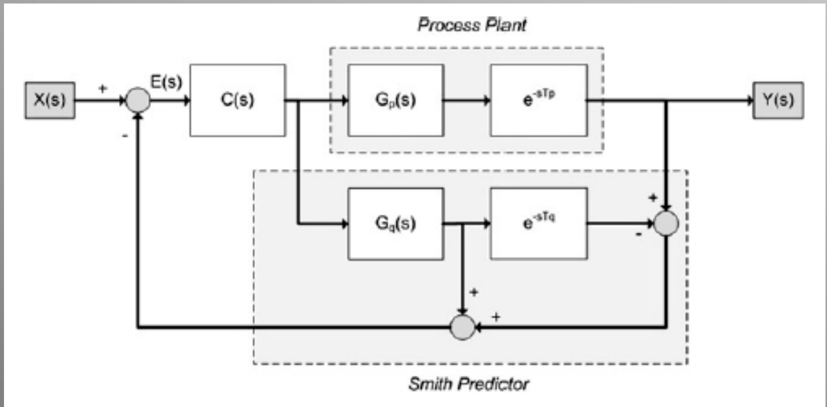
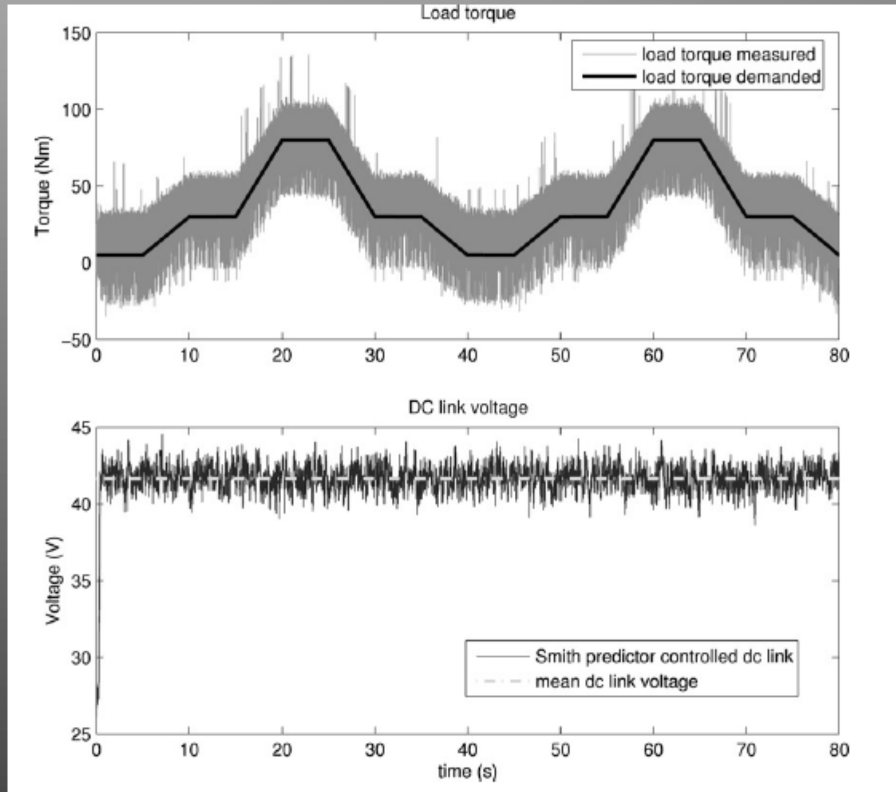


Excellent stability achieved

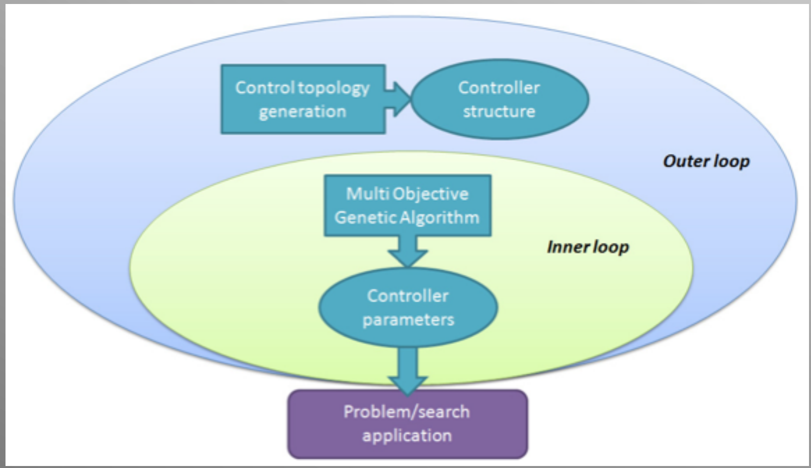
Controller relies on accurate models of both the system and the lag

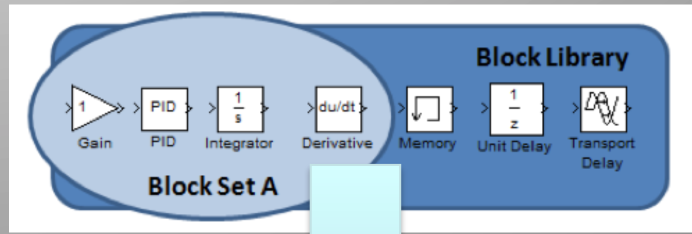
Computationally intensive

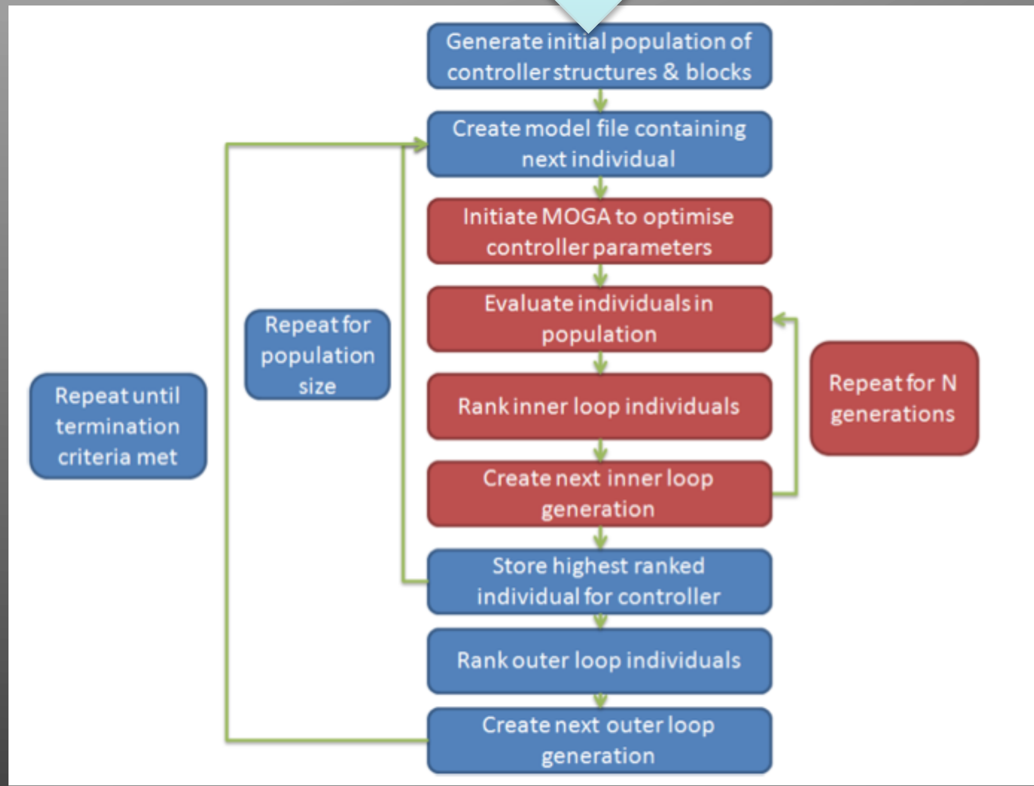
Could be adaptive, but with added complexity



Predictive time delay controller







Automated method to:

- Design controller structure
- Design controller interconnections
- Optimise controller parameters

- Implemented in Simulink

A Genetic Programming Approach

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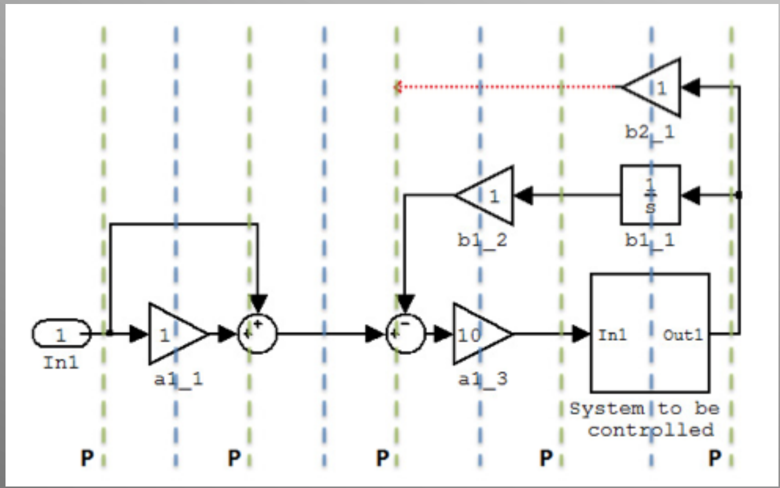
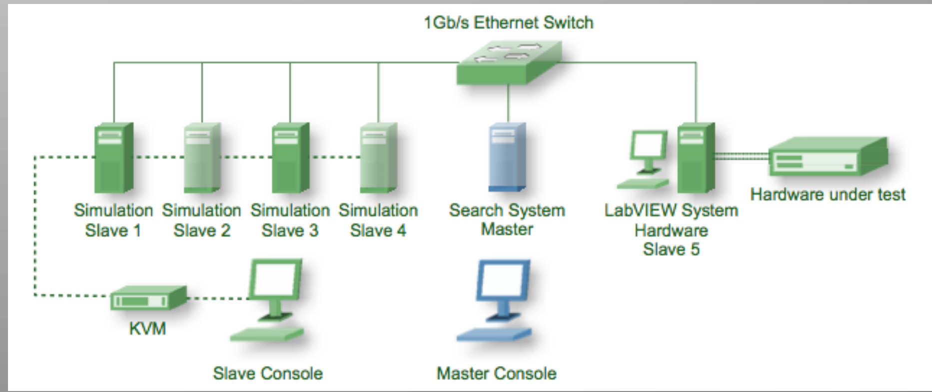
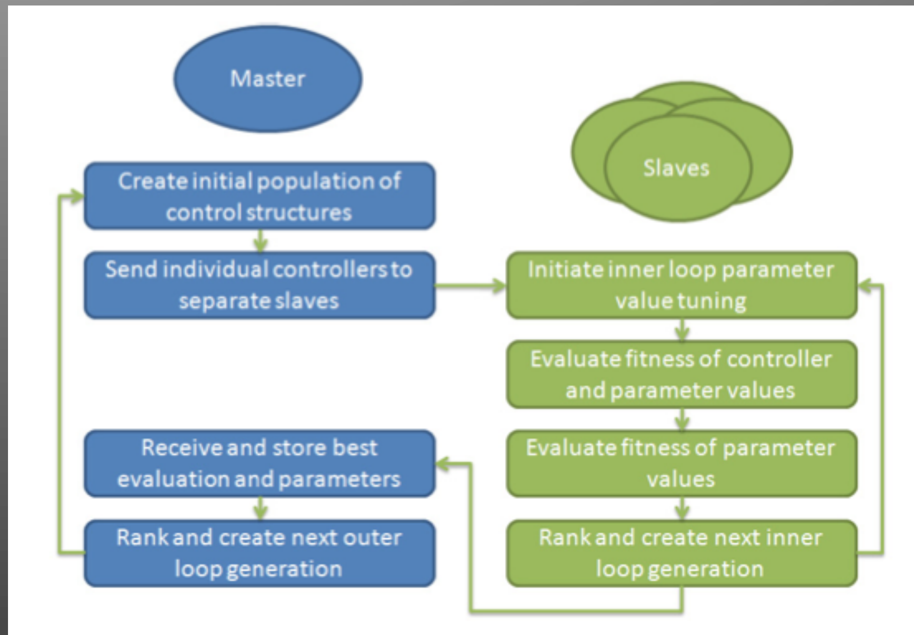




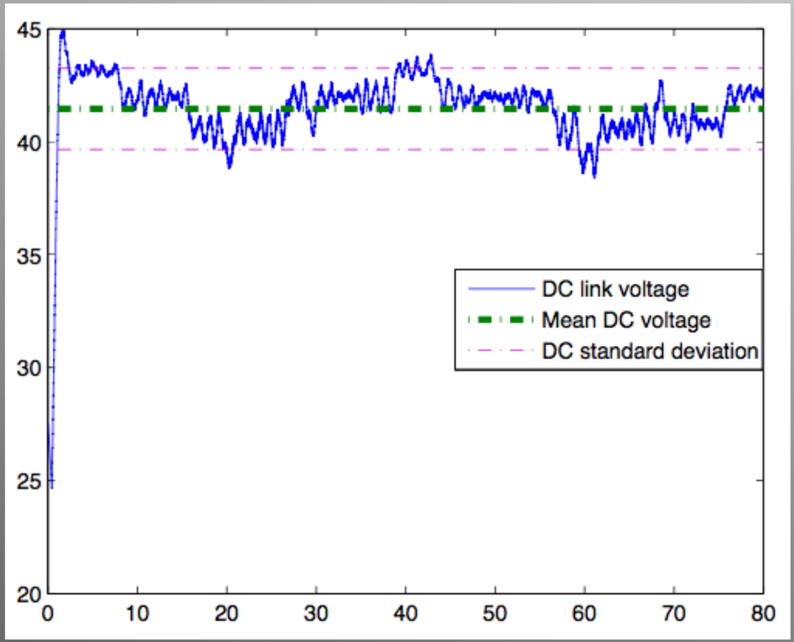
Computationally intensive method:

•Individuals in the GA are distributed across multiple processors

•LabView interface to hardware in the loop

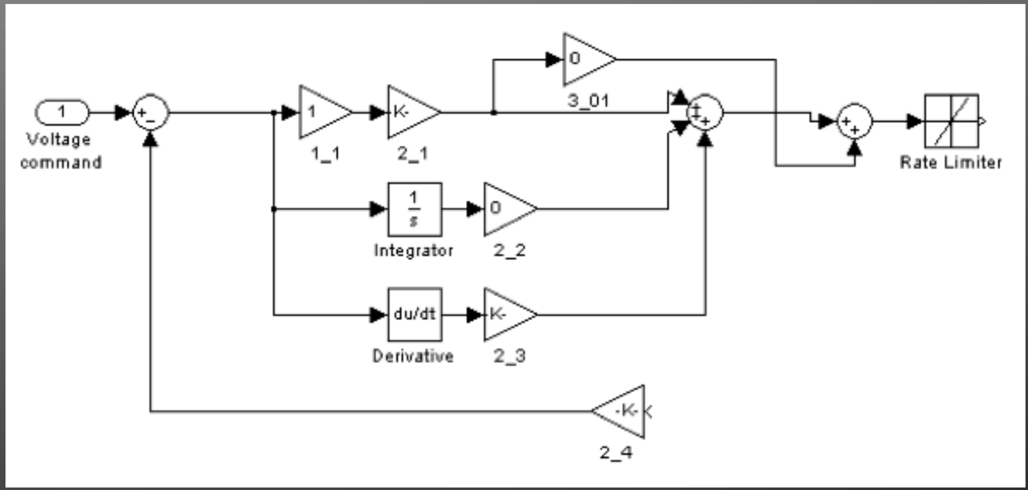


A Genetic Programming Approach II



- Controller structure and gains are evolved in Simulink by Genetic Algorithms
- Block interconnections chosen by intelligent agents.
- Design carried out on nonlinear engine model

- Improved controlled response over standard controller methodologies
- Implementation computationally simple
- Does not rely on real time system or delay model
- Has robust features



Genetic programming designed controller

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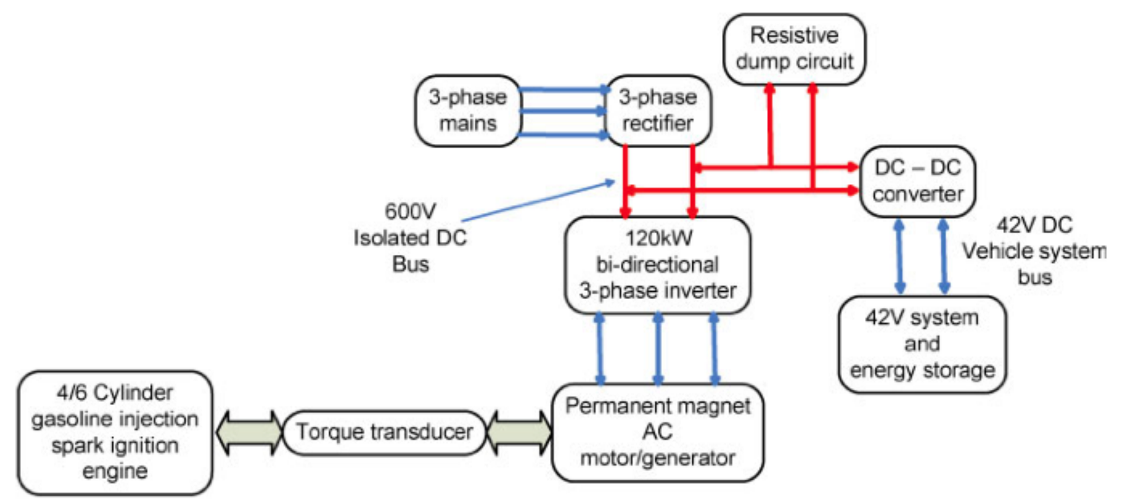

An examination of intelligent methods vs designed experiments

Objective: to find the maximum fired cylinder pressure point for an 'unseen' experimental engine

Data to be used in linear electrical machine design

Designed to control novel piston trajectories in free piston HEV engine

Hardware in the loop analysis

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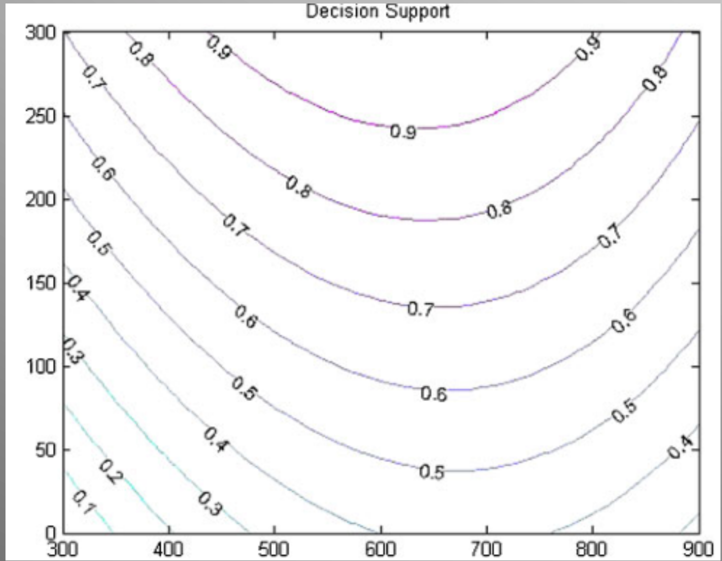

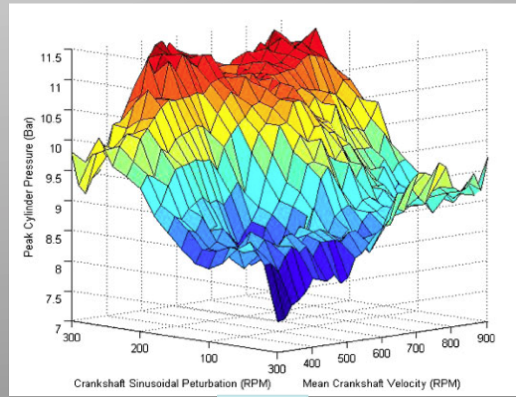

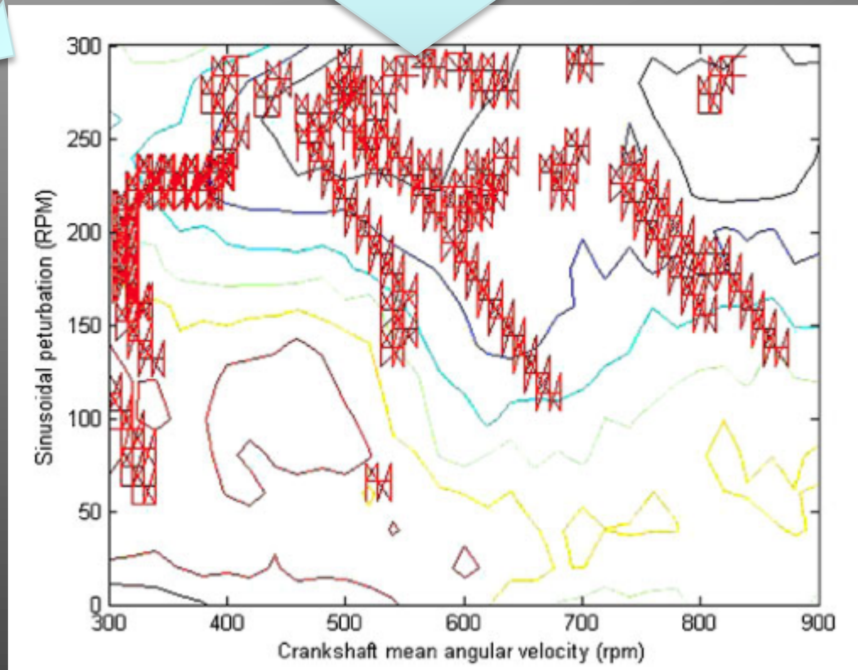

Experimental parameters are guided by gradient ascent expert system

Expert system updated in real-time

Automated experimental procedure

Example 90*30 experimental matrix = 2700 steps

Expert system averaged 30 steps

Results of automated experiments

•Electronic throttle control opens up numerous opportunities for DC Link voltage stabilisation
•Engine lag makes PID implementation problematic
•Predictive methods overcome engine lag at the expense of robustness and complexity
•Potential to overcome predictive shortcomings with adaptive methodologies, but computationally expensive
•Novel AI methodology presented to optimally evolve control architectures
•Novel HIL methodology presented to reduce experimental cost

FUTURE

HIL robust design
Multivariable control methodologies
Novel HEV engine-generator combinations

Conclusions